LEVEL

(2)

NRL Memorandum Report 4600

A106747

HF Systems Test for the SURTASS Operation of February 1981

D. R. UFFELMAN AND L. O. HARNISH

Ionospheric Effects Branch
Space Science Division
E.O. Hulburt Center for Space Research

October 26, 1981

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(12) 16

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 4600	2. GOVT ACCESSION NO. AD-A106747	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) HF SYSTEMS TEST FOR THE SURTASS OPERATION OF FEBRUARY 1981		5. TYPE OF REPORT & PERIOD COVERED Interim report on a continuing NRL problem.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) D. R. Uffelman and L. O. Harnish		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, DC 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 41-0208-0-1
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Electronic Systems Command, PME 124.4 Arlington, VA 20360		12. REPORT DATE October 26, 1981
		13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) (11) 26 Oct 81		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

(14) NRL-MR-4600

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Frequent management
Oblique sounding
Channel evaluation
HF communications

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this document is to discuss preliminary results of the SURTASS HF systems test conducted in the Atlantic during February 1981 from the point of view of the condition of the HF propagation channel as determined by the Barry oblique sounder equipment (AN/TRQ-35). The initial analysis indicates that the primary difficulty in maintaining a high reliability HF circuit with the requisite data rate can be attributed to

(Continues)

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

251150

20. ABSTRACT (Continued)

inappropriate frequency selection arising from procedural difficulties, a general lack of anticipation of the optimum frequencies as dictated by ionospheric channel charac-teristics and possible interference effects. Channel evaluation as performed by NRL personnel using sounder equipment suggests that reliability may have been improved significantly had available information been entered directly into the frequency management process.

CONTENTS

HF Systems Test for the SURTASS Operation of February 1981

1.0 PREFACE

In order to put the comments made herein into proper perspective, the authors acknowledge that we are generally unacquainted with the details of the SURTASS program. Hence, a few statements follow which indicate points of reference from which we are working. First, it is understood that the SURTASS system is in a preliminary production phase. In addition, we sense that the requirement imposed on SURTASS to have a reliable HF backup capability to transmit data to shore sites is somewhat recent. As a result, it appears that SURTASS is in a production mode with an HF backup capability which is still in the research phase.

We suspect the requirement to have an HF backup capability is an untimely annoyance. It should be emphasized that in a stressed military environment, it is possible that satellite assets will be overloaded and perhaps even non-existent. Hence, the ability to utilize an effective HF communications capability takes on greater importance from the point of view of SURTASS meeting its objectives in the future. Since the HF capability has a number of questions yet to be answered, we believe the HF tests should be more research oriented. Here, advantage should be taken of all the diagnostic tools that can be mustered as well as a concerted effort made to test one variable at a time while holding remaining variables constant. This latter suggestion should facilitate the analysis of experimental results since the decoupling of variables would not have to be done.

2.0 BACKGROUND

Workers who are well acquainted with the HF band know that in a low noise environment reliable HF communications can be maintained at reasonable data rates provided the proper frequency, bandwidth, and antenna are selected. In fact, if these items are optimized, it is reasonable to expect reliabilities approaching those of satellite links. Unfortunately, because of the nature of the beast, the information bandwidth is not as great as with satellite systems. Typically, the tack taken is to devise equipment and techniques to improve the system performance under poor channel conditions. Work devoted to this end include improved antenna design, increased transmitter power, modulation and detection techniques commensurate with the medium, diversity techniques, and error correction techniques. These methods offer some improvement, but the performance of the channel generally remains below that desired. A substantial improvement, however, can be gained by selecting the optimum channel between the transmitter and receiver. This is the role of the oblique sounder and techniques relying on it.

Manuscript submitted June 25, 1981.

3.0 DISCUSSION

3.1 Sounder Utilization

In the test addressed herein, SURTASS wisely authorized the use of HF channel evaluators, i.e., oblique sounders, to determine the characteristics of the HF channel. This information was to be used on shore to optimize frequency selections in order to obtain a more accurate test of the HF equipment which is currently envisioned as part of the final system. In addition, sounder data is being used in the analysis to provide 20/20 hindsight. Finally, some discussion was given to evaluating the role sounders as part of the SURTASS system. It can probably be decided at the outset that oblique sounder transmitting equipment should not be part of the final SURTASS complement at sea since this broad spectrum emitter could degrade the ability to be current. Perhaps some consideration might be given to including the spectrum monitor and receiver at sea to aid in frequency selection since these equipment are passive in nature. However, the recent test emphasized the great extent to which the ship's HF communications is at the mercy of the frequency controllers at the land sites. This gear would probably be an expensive under utilized add-on. In effect, therefore, it would appear that in the final system, even the spectrum monitor and receiver would not need to be part of the ship's equipment complement.

Serious consideration should be given to incorporation of a PROPHET-type technology with a real-time update capability in the SURTASS system. Since the SURTASS ship has a large enough computer system to handle the data collection and compression, the capability probably exists to have a software module which selects in a dynamic fashion the proper frequencies and equipment assets the ship should use to transmit its message in the most efficient manner back to a shore site. This module would generally be updated by the shore site, but if contact is lost, the technique has shown a reasonable persistence. This model update scheme is precisely the problem that NRL is addressing in the context of the NOSC PROPHET system. Although the work appears at first to be somewhat unrelated to SURTASS, the input to and results from the SURTASS HF tests fits hand in glove with the objective of optimizing the production system.

3.2 Diurnal Channel Variability

As suggested earlier, proper frequency selection for a circuit is the cornerstone of a highly efficient HF link operating at reasonable data rates. Figure 1 is an example which demonstrates qualitatively how circuit frequency selection should be accomplished throughout the day. Essential to this task are four elements: a) accurate information regarding the HF channel between the transmitter and receiver, b) a large number of appropriate frequencies available in the frequency pool, c) the ability to select new frequencies and change in a coordinated manner before the channel begins to deteriorate, and d) equipment assets to do the job once the parameters are known.

Notice in Figure 1 that for a 24-hour period one could do quite well with five separate frequencies. Starting at mid-path sunrise the characteristics of the channel begin to change very rapidly. Ideally, with a large number of frequencies one could anticipate this change and move up in fine steps along the curve of optimum transmission frequency (FOT) until reaching a point in mid-path morning where one frequency would be good for

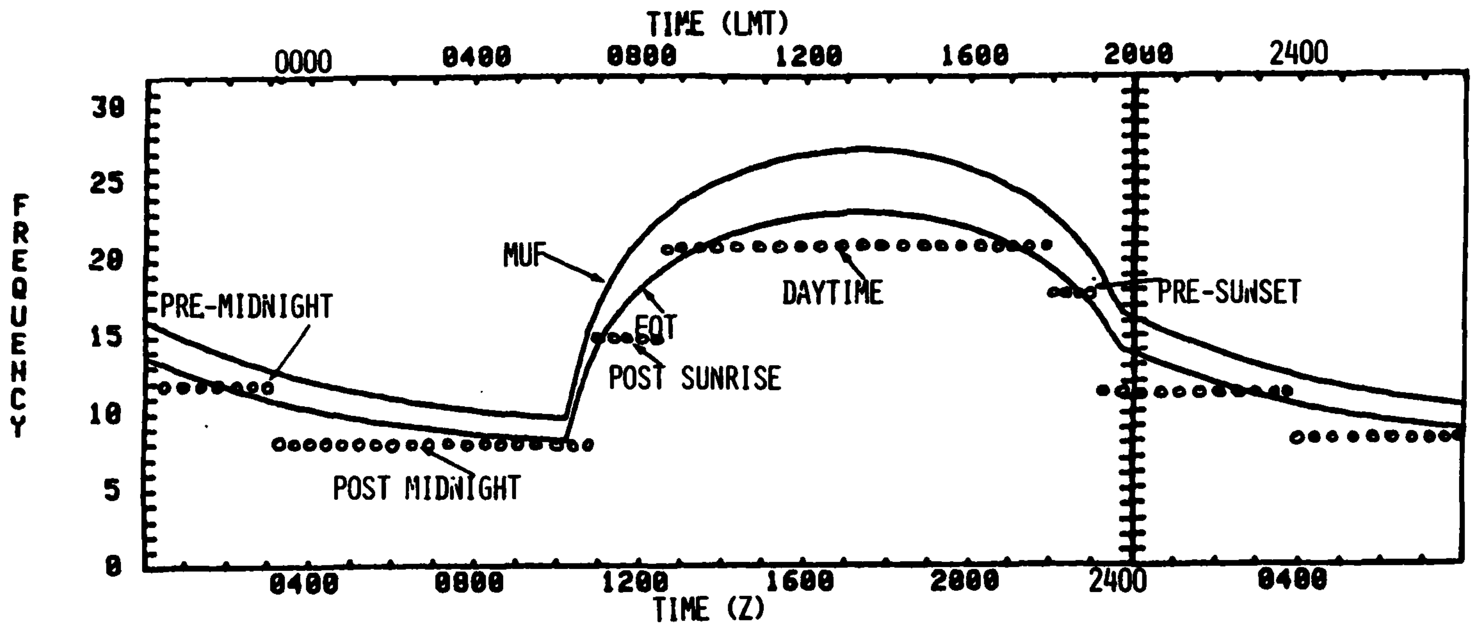

Fig. 1 — Example frequency selection strategy based upon the diurnal variation of the HF channel

most of the mid-daylight hours. As the sun starts to go down in the afternoon, one should apply the same technique in reverse; that is, stepping down in frequency in fine steps to match the FOT curve. After sunset a pre-midnight frequency is used. As midnight approaches, the frequency is further dropped. This is the post-midnight frequency and is used until the sun rises in the morning.

It is reiterated that the local time which is used in this analysis is that of the mid-point of the circuit. In some of the data presented later, it appears that the frequency controllers had some knowledge of the daily variation of the HF channel, but they were using their local time instead of the mid-path local time. Hence, the stepped frequency function was shifted toward the nighttime and thereby as the nighttime approached, reliability of the circuit was probably greatly degraded. In summary, accurate knowledge of the diurnal variation of the HF channel can allow one to anticipate frequency changes before the channel begins to degrade. This technique could be performed quite effectively with five frequencies per day as suggested by Figure 1.

4.0 RESULTS

4.1 The Actual Frequency Strategies

With the preceding sample diurnal variation of the channel in mind, consider Figure 2. Indicated in this figure is the maximum usable frequency (MUF) between the ship and Driver, Va. as measured each hour by the sounder which was set up to measure this circuit. This is the upper meandering curve that goes throughout the figure. No propagation over the circuit should be expected above the MUF. The vertical lines are the bands of optimum transmission frequencies as scaled from the sounder data. Bands of optimum transmission frequencies are regions in the sounding data defined as having high signal strength and no observed multipath. The lower meandering curve is the lowest usable frequency (LUF) as scaled from the sounder data. Again, greatly attenuated skywave propagation should be expected below the LUF. A dotted line on the MUF or LUF indicates the ship's transmitter interfered with the sounder data and a clear value for that parameter could not be obtained.

Superimposed on the scaled sounder data are the frequencies which were used by the ship to communicate with the shore. At a meeting with the frequency controllers in Norfolk, it was stated that the receiver site which was used most of the time was located at CAMSLANT. Hence, for the period of time that the HF sounders were operating at Driver, a plot of that data vs the selected frequencies is presented. Utilization of other receiver sites should be included in the final analysis, however. If the frequency selections were made in a knowledgeable manner, one should see a stepped function as approximated by the example in Figure 1.

Several items, therefore, should be quite striking upon examination of Figure 2. First, on February 16 and 17, the frequency selections apparently were made with no consideration of the diurnal variation of the HF channel. On February 16, a flat frequency selection was made. On the 17th, the frequency selection was almost as bad since the selection in no

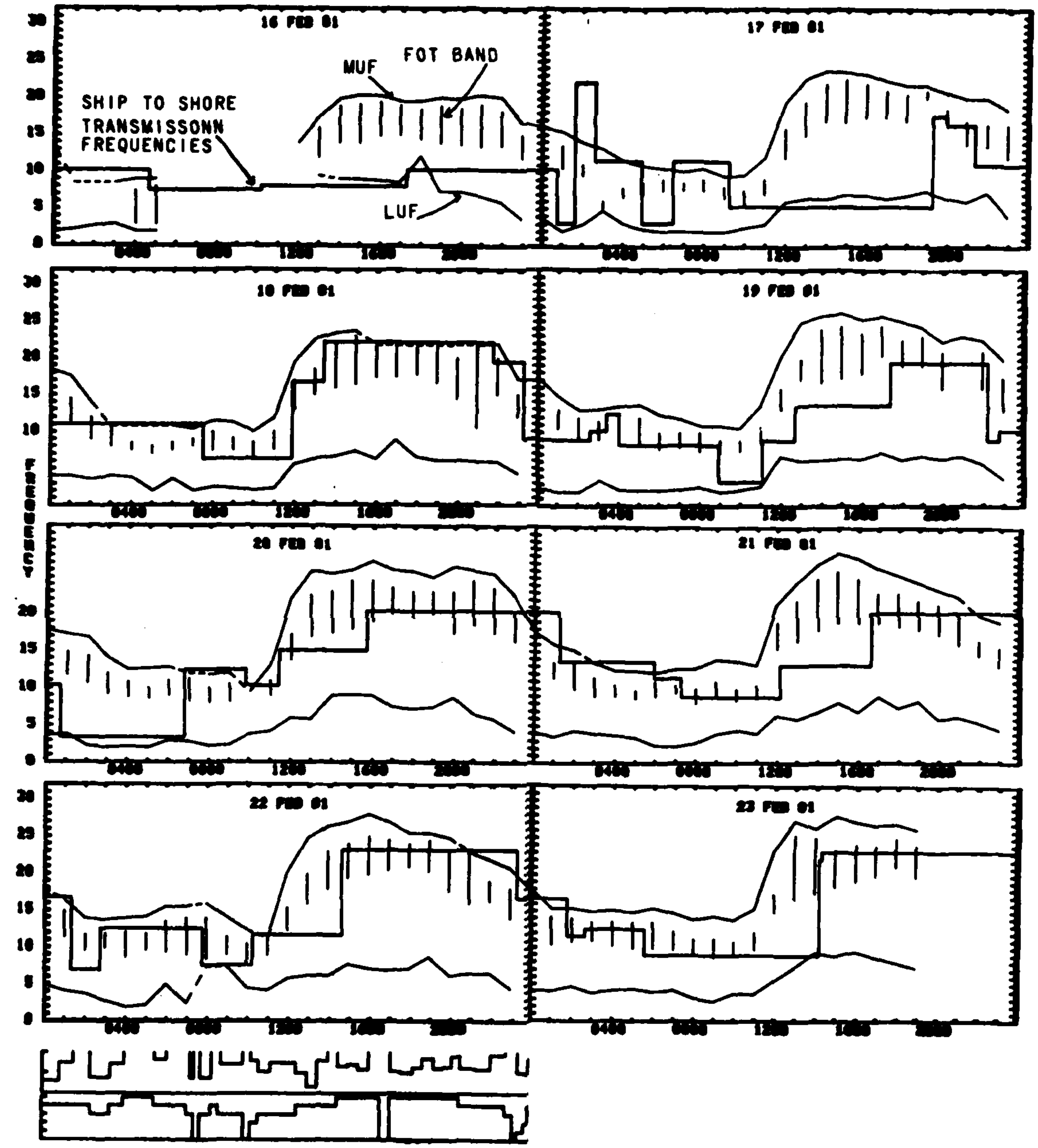

Fig. 2 — Comparison of active frequency selection with oblique sounder measurement from Driver, Virginia to the ship

way resembles the diurnal variation of the channel. Notice, in fact, that the selected frequency crosses into the lowest usable frequency over the path indicating there should have been poor communications for most of the morning. Finally, near the end of the day the selection of frequencies improved since frequencies approaching the FOT were selected. On Feb 18, the selection improved greatly. On the following days there was apparently more effort to make frequency selections based on the diurnal variation of the channel but there is a marked shift to the right indicating the frequency manager may have been using his local time instead of mid-path local time to do the selection, or a different receive site was being used. The Sugar Grove receiver would have yielded a better fit in this case.

In a final analysis, the frequency selection should be correlated with the bit error rate (BER) and the baud rate to determine how well the frequency selection was performing. Additionally, an indication of the interference environment should be included since an apparently good frequency selection could yield a large BER due to interference. Unfortunately, only some qualitative interference data exists. Two other factors to be folded in the analysis are the exact receive point and the ship's track. These are important since channel characteristics are a function of circuit geometry. It is understood that at least three different receiver sites were used. CAMSLANT was apparently the predominate site, Sugar Grove a second one, and a site in Florida a third. Only hourly values were scaled from the sounder data in its preliminary analysis. Data exists every 15 minutes and will be presented at a later time.

The overwhelming message drawn from figure 2 is that the frequency selection done by the shore site was poor indeed, and it should not be surprising that the HF channel performed poorly.

4.2 PROPHET Predictions

Mention has been made that a previous test had better results using the PROPHET prediction system. PROPHET predictions are better than to have no knowledge at all. To show this, figure 3 was constructed. Figure 3 contains plots of the PROPHET predictions of MUF overlayed on the actual sounder data for the Driver link. Also noted is the RMS error between the maximum usable frequencies as measured by the Barry sounding equipment and those computed by the model in the PROPHET system. The errors are well within those quoted for PROPHET. Plotted parallel to the MUF is the contour which is .85 of the predicted MUF. This is the predicted FOT. Notice in comparing this with the previous figure that if the frequency controllers had used their PROPHET prediction they would have obtained diurnal frequency variations which would have been quite close to the proper ones. However, the RMS error between the PROPHET computations and the channel evaluation are still significant.

4.3 Enhanced PROPHET

At the pre-sail meeting, NRL representatives suggested that the frequency controllers use their PROPHET system but driven with an effective sunspot number or 10.7 cm flux as deduced from the sounder data by the NRL

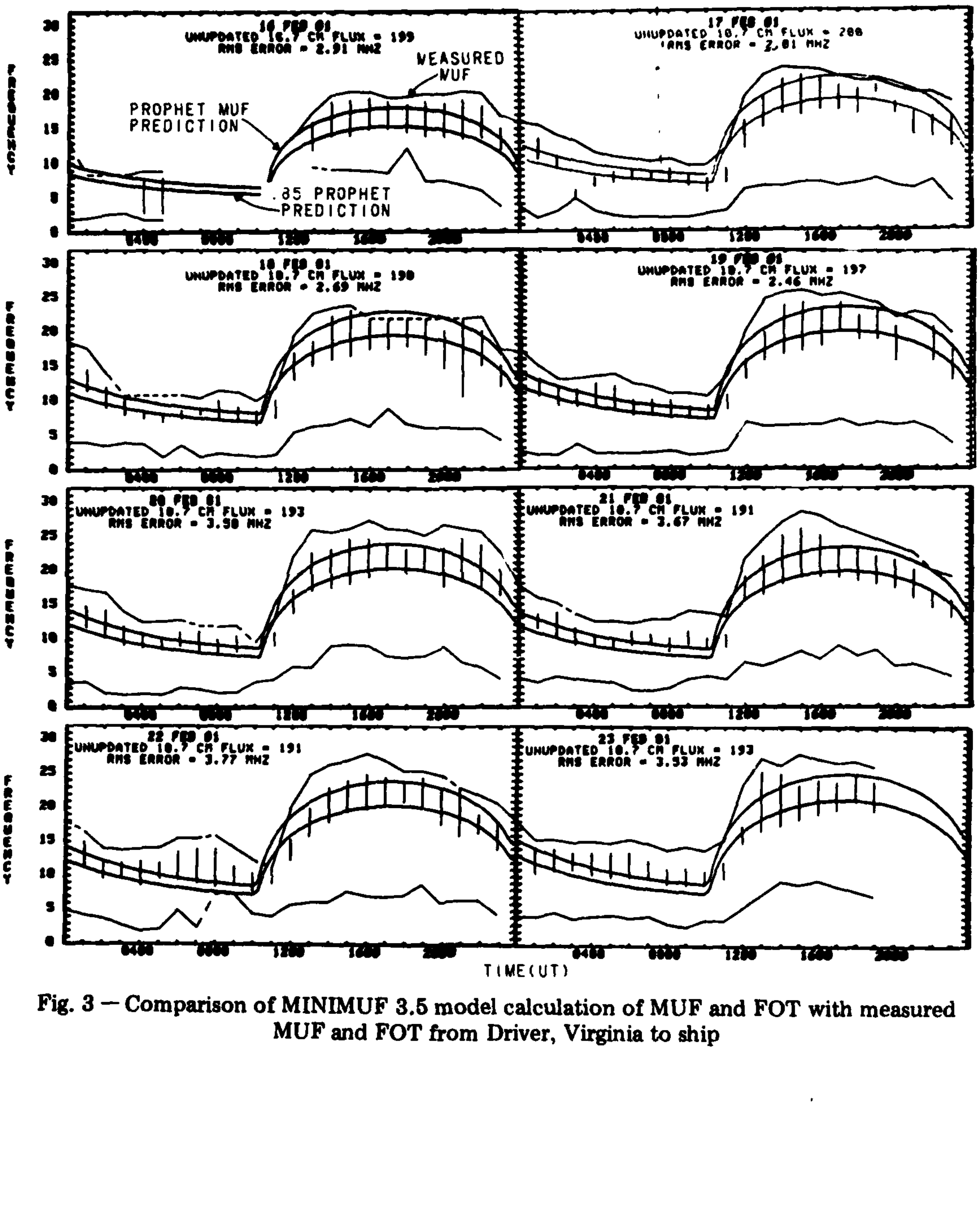

Fig. 3 — Comparison of MINIMUF 3.5 model calculation of MUF and FOT with measured MUF and FOT from Driver, Virginia to ship

representative on the ship. Although NRL's purpose on board the SURTASS ship was to obtain and interpret the oblique sounder data in support of SURTASS, we further attempted to send an index (updated sunspot number) back to shore site personnel for them to use in their PROPHET system to determine diurnal trends as they were being measured on the ship. Figure 4 is a comparison between the measured maximum usable frequency obtained from the Barry equipment and the updated model. The updates were taken at either 1200Z or 1400Z for this analysis. There is a clear improvement of the fit over the unupdated PROPHET prediction. Table I below summarizes the improvement yielded by the update. These numbers are preliminary since they were drawn from hand scaled hourly measurements. The results are expected to improve further when 15 minute values are taken from the sounder data and ships position is taken into account in a like manner.

Improvement of Forecast Due to Model Update

TABLE I

DATE	RMS Error (MHz) UNUPDATED	UPDATED	UPDATED TIME (UT)
16 FEB	2.91	1.23	1400
17 FEB	2.01	1.71	1200
18 FEB	2.69	2.10	1400
19 FEB	2.46	1.57	1200
20 FEB	3.50	1.61	1400
21 FEB	3.67	2.22	1200
22 FEB	3.77	2.15	1400
23 FEB	3.53	2.33	1400

To emphasize the fact that the updated PROPHET could have been effectively used to make frequency assignments, figure 5 is included. This figure indicates the updated model prediction as compared with the actual frequency assignment. In addition, the dotted line indicates the manner in which frequency assignments could have been made if these data had been used. This proposed frequency selection was constructed from ship assigned frequencies. On one day only, Feb 18, did the actual frequency assignment closely approach an optimum frequency assignment scenario. On the other days, the actual frequency assignments departed significantly from that which was desirable.

In several places, e.g., Feb 19 between 0900 and 1100Z, a frequency shift was made away from what appeared to be the correct frequency. Areas such as this should be examined carefully to shed light on the reason for the shift. It is possible that interference occurred and the frequency was

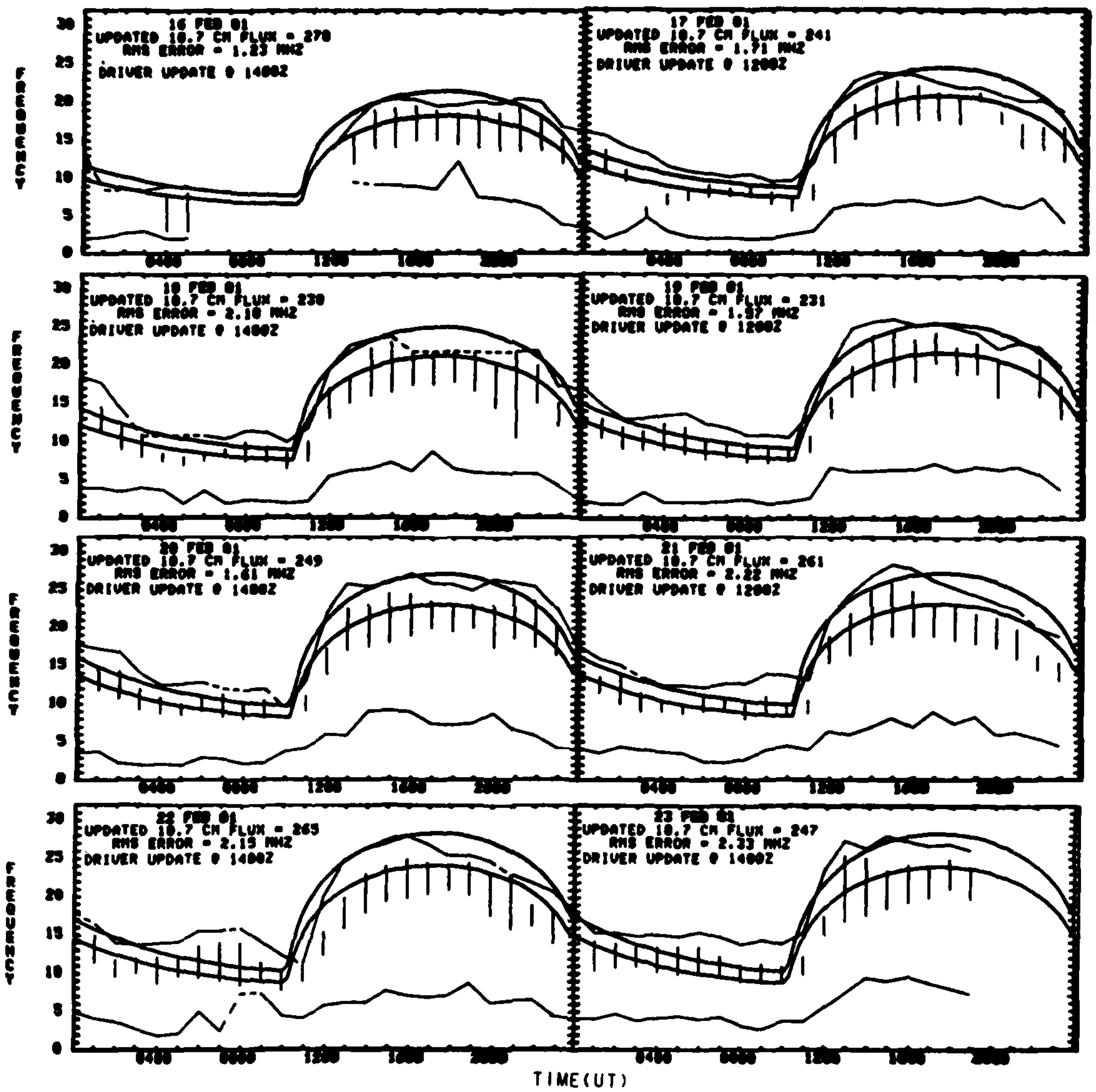

Fig. 4 — Comparison of updated MINIMUF to actual measurements

shifted in order to get away from that interference as receiver sites were changed. For the data in general, further examination of bit error rate and baud rate data in conjunction with the actual diurnal frequency selection should reveal additional interesting points. Unfortunately, there will likely be some unanswered questions since a total picture of communications environment especially in the area of radio frequency interference (RFI) was not obtained.

5.0 SUMMARY

The major problems encountered during this test were poor frequency assignment strategy, inadequate anticipation of frequency changes, and generally poor procedures. It appears as though neither a PROPHET capability nor an updated PROPHET capability based on the oblique sounder was utilized. Hence, poor results should be expected. Use of these techniques probably could have greatly increased circuit performance. The lack of information regarding radio frequency interference on an existing frequency which is indicated as a good frequency by the sounder will be a hole in further analysis. Finally, the ability to deduce channel performance from bit error rate and baud rate data is hampered since there is a relationship between bit error rate (BER) and baud rate in the presence of multi-path.

6.0 RECOMMENDATIONS

The following suggestions are made to improve testing in the future:

A. Mount the sounder transmitter on board the ship and give the shore receiver site the receiver and spectrum monitor. This will give the frequency controllers direct access to the channel evaluation data. Care must be taken, however, to record a total set of pictures of the oblique ionograms for later analysis as well as information from the Barry spectrum monitor indicating RFI problems.

B. Run for several days at a constant baud rate and minimize BER through careful selection of frequencies. The idea here is to decouple the relationship between BER and baud rate by holding baud rate constant. Hence, BER alone would be an indication of the performance of the channel under optimum frequency selection. This should not be considered an operational test in the sense that the sole objective is to get the most operational useful data through. This would be a test with the primary objective of determining the effect of procedures to optimize frequency selection and success could be measured directly by BER. In conjunction with this test, interference information as obtained from the spectrum monitor is mandatory.

C. Finally, as part of the final configuration, SURTASS should seriously consider some type of HF multiplexer to multiplex the order wire and data channels into one data stream. This will allow transmission on 3 kHz channel assignments and has the effect of

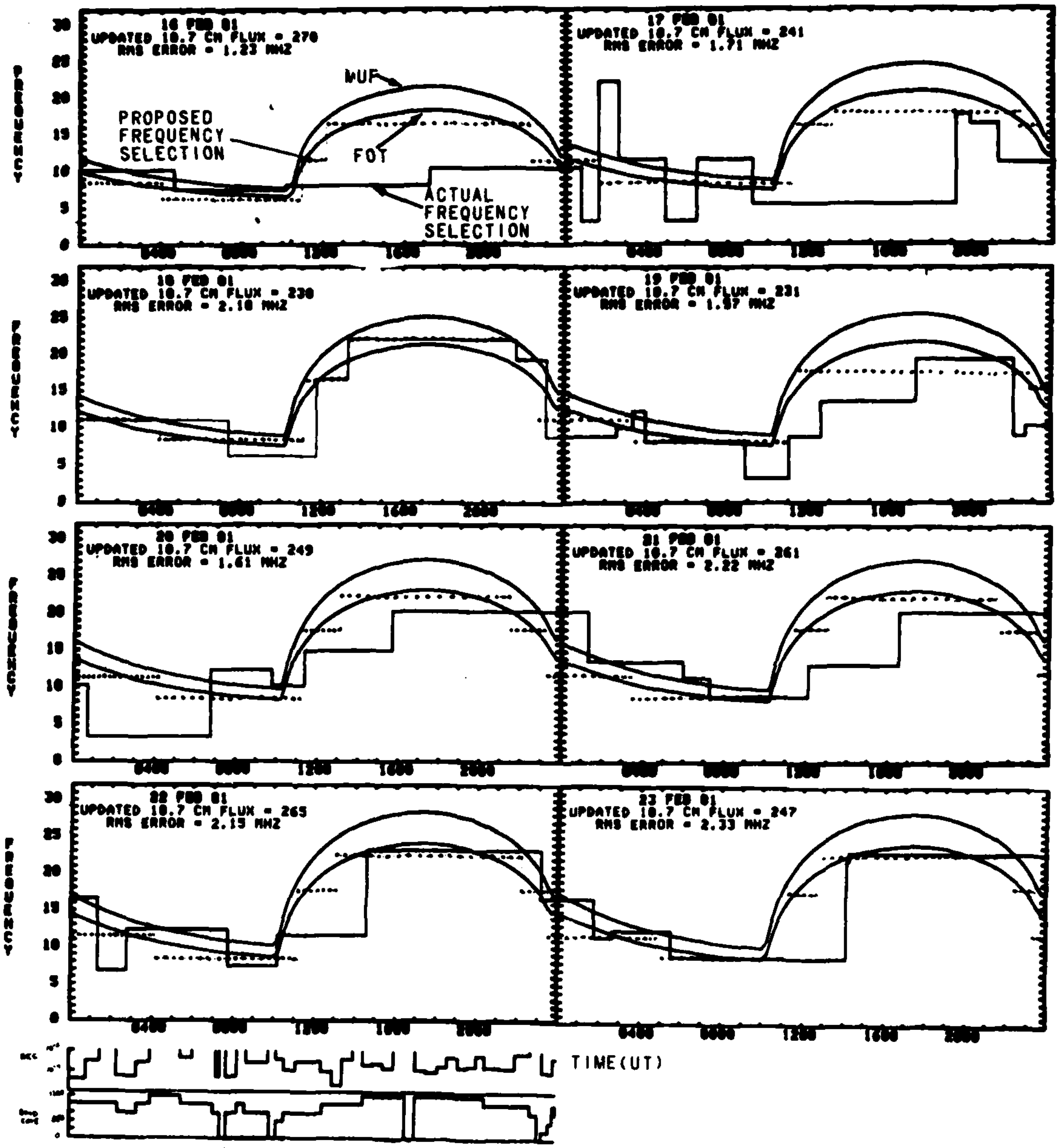

Fig. 5 — Comparison of "hindcast" frequency selection vs actual frequency selection for ship to shore circuit

opening up the amount of frequencies one has available from which to select. To test this idea without going to the expense of buying a multiplexer, one would simply eliminate the order wire function and transfer that function to the satellite link during the testing period.

NRL would like to take part in future tests from the point of view of obtaining the oblique sounder data from several paths from which we can test our update algorithm. This has great potential impact on the SURTASS system since this could lead to a decision to include in SURTASS a PROPHET-like system incorporating update to maintain a highly efficient HF channel.

In the near future, further BER and baud rate information should be examined in conjunction with a finalized form of the data presented here. In addition, the model update scheme will be examined as it applies to anticipating frequency changes and maintaining high quality data channel in the context of the SURTASS operations.